

1 **METHOD OF MEASURING THE AZIMUTH AND RESETTING ZERO**
2 **AZIMUTH AUTOMATICALLY**

3 **BACKGROUND OF THE INVENTION**

4 1. Field of the Invention

5 The present invention relates to a method of measuring the azimuth and
6 resetting to zero azimuth automatically, in particular to a method of precision
7 tuning the longitudinal and latitudinal zero reference values in an azimuth meter
8 in preparation for accurate measurement of the azimuth.

9 2. Description of Related Arts

10 Azimuth meters in general are either mechanical or electronic.
11 Mechanical azimuth meters are low cost but their readability and accuracy are not
12 very good. Electronic azimuth meters are favored by mountaineers and
13 navigators as they possess high precision and good readability.

14 The electronic azimuth meter performs azimuth measuring with two
15 orthogonal magnetic sensors. Intensity values of earth magnetism at the
16 measuring site are collected by the magnetic sensors, and then output the
17 corresponding sine wave signals. The electronic apparatus picks up the sine wave
18 signals representing the earth magnetism at the site, processes the measured
19 values through internal computation, and outputs the azimuth on the screen of the
20 electronic apparatus. Since an electronic azimuth meter can rely on the internal
21 electronic circuits to compute the azimuth, it does not need the realignment of the
22 pointer scaling necessary for mechanical azimuth meters. However, it is
23 necessary to set the conversion standard value, basing on which the sine wave
24 signals output by the magnetic sensors can be processed to compute the azimuth,

1 which means every electronic azimuth meter should have the capability of
2 resetting to zero azimuth automatically in order to generate an accurate
3 measurement of the azimuth.

4 The current practice of resetting to zero azimuth in an azimuth meter is
5 by using two orthogonal oriented magnetic sensors to take sample measurements
6 orthogonally. Since the two sine wave signals output by the two magnetic sensors
7 are each out of phase by 90 degrees, the computation for the azimuth can be
8 simplified by taking the two values having 90 degrees phase angle as the zero
9 reference values. The output sine wave signals represent the magnitude of earth
10 magnetism at the measuring site in the longitudinal and latitudinal orientations. If
11 the measuring site is located in both high longitudinal and latitudinal coordinates,
12 the amplitude of the sine wave signals will tend to increase in proportion to the
13 angular coordinate, but if the measuring site is located in positions with large
14 difference between the longitudinal and latitudinal coordinates, then the
15 amplitude of the sine wave signals will vary greatly. Even with adjustment of
16 zero azimuth at the first measuring site (x_1, y_1) to generate adjusted zero
17 reference values (X_0, Y_0). If the measuring site is moved to a second location
18 (x_2, y_2), the computation of the azimuth still causes overflow errors. Therefore,
19 the precision and applicability of conventional azimuth meters, as shown in Fig. 5,
20 are considerably discounted.

21 22 SUMMARY OF THE INVENTION

23 The main object of the present invention is to provide a method of
24 measuring azimuth with the capability to reset to zero azimuth automatically to

1 assure accurate measurement of the azimuth even if the measuring site with large
2 coordinate difference is moved after the zero azimuth adjustment.

3 To this end, the main instrumentality comprises the steps of taking a
4 series of samples with two orthogonal magnetic sensors and outputting
5 corresponding first and second sine wave signals, adjusting the amplitude of one
6 of the two sine wave signals to cause the amplitude of both sine wave signals to
7 be of equal amplitude, computing the average on the basis of the maximum and
8 minimum values of the first and second sine wave signals from the two
9 orthogonal magnetic sensors, and taking the resultant average values of the
10 respective sine wave signals as the zero reference values for use in subsequent
11 measurement of the azimuth.

12 The above-mentioned steps of resetting to zero azimuths involve
13 sampling the maximum and minimum values of the first and second sine wave
14 signals from the two orthogonal magnetic sensors, and then these two sine wave
15 signals are normalized by equalizing their amplitudes to avoid errors due to large
16 coordinate differences. With automatic adjustment for zero azimuth, the
17 measurement of the azimuth can be obtained at any place, with no limitation on
18 movement and positions of the measuring site. Sample measurements are taken
19 by the two orthogonal magnetic sensors, which then output the corresponding
20 first and second sine wave signals in longitudinal and latitudinal directions.
21 Again, through suitable amplitude adjustment, the two sine wave signals are
22 matched against the corresponding zero reference values to come up with the
23 azimuth at the site.

24 The features and structure of the present invention will be more clearly

1 understood when taken in conjunction with the accompanying drawings.

2 BRIEF DESCRIPTION OF THE DRAWINGS

3 Fig. 1 is a procedural flow of resetting to zero azimuth in accordance
4 with the present invention;

5 Fig. 2 is a waveform diagram of the first and second sine wave signals;

6 Fig. 3 is a procedural flow of the process of measuring the azimuth at a
7 measuring site;

8 Fig. 4 is a representation of the azimuth taken by the present invention;
9 and

10 Fig. 5 is a representation of the azimuth taken by conventional azimuth
11 meters.

12 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

13 The present invention provides a method of measuring the azimuth for
14 resetting to zero azimuths automatically to be used on azimuth meters for rapid
15 calculation of the azimuth. The azimuth meter, in accordance with the present
16 invention, is operated by two orthogonal magnetic sensors, which take samples
17 with different azimuths in longitudinal and latitudinal orientations, and output
18 the sine wave signals corresponding to the magnitude of measured earth
19 magnetism in the longitudinal and latitudinal directions for computation of the
20 zero azimuth.

21 The resetting to zero azimuth, as shown in Fig. 1, is performed by means
22 of two orthogonal magnetic sensors installed in an azimuth meter. Basically, the
23 process of resetting to zero azimuth is to be accomplished in four stage processes,
24 as shown in Fig.1.

1 collecting multiple sets of samples from different azimuth angles, using
2 the two orthogonal magnetic sensors, and outputting corresponding first and
3 second sine wave signals (S_x) (S_y) in longitudinal and latitudinal orientations,
4 whereby the first sine wave signal (S_x) and the second sine wave signal (S_y) are
5 90 degrees out of phase with each other;

6 adjusting the amplitude of one of the two sine wave signals (S_x/S_y) such
7 that the amplitude of the first sine wave signal (S_x) and the amplitude of the
8 second sine wave signal (S_y) are of equal amplitude, as shown in Fig. 2;

9 computing the average values (X_{base} , Y_{base}) basing on the maximum
10 and minimum values of the first and second sine wave signals (X_{max} , Y_{max});
11 and

12 taking the average values (X_{base} , Y_{base}) for the first and second sine
13 wave signals (RS_x , RS_y) to be zero reference values, whereby the positive and
14 negative sides of the reference sine wave signals (RS_x , RS_y) are of equal
15 amplitude.

16 Furthermore, likes the above mentioned first stage process,
17 taking four samples in the first set (X_1 , X_2 , X_3 , X_4) (Y_1 , Y_2 , Y_3 , Y_4) by
18 each magnetic sensor respectively; and compares the first set to find the
19 maximum and minimum values (X_{max} , X_{min}) (Y_{max} , Y_{min}) among the sample
20 values in each set to support the above mentioned third stage process to average
21 the values.

22 In the above-mentioned second stage process, the way to adjust the
23 amplitude of the first and second sine wave signals (S_x) (S_y) is by comparing the
24 maximum value (X_4) of the first sine wave signal (S_x) with the maximum value

(Y1) of the second sine wave signal (Sy) to yield a differential ratio $R1 = X4/Y1$ or $R2 = Y1/X4$, and then either the second sine wave signal (Sy) is multiplied by the ratio R1 or the first sine wave signal (Sx) is multiplied by R2 to make the amplitudes of the first and second sine wave signals (Sx) (Sy) of equal amplitude.

Finally, the third-stage process is for computing the average values (Xbase, Ybase) basing on the maximum and minimum values (Xmax, Xmin) (Ymax, Ymin) among the sample values in each set.

The computation of average values (Xbase, Ybase) in the third stage can be expressed by two formulae:

$$X_{base} = \frac{X_{max} + X_{MIN}}{2}$$

$$Y_{base} = \frac{Y_{max} + Y_{MIN}}{2}$$

As shown in Fig. 3, the computation of average values to yield the azimuth comprises the steps of:

taking the first and second sample sets with the two orthogonal magnetic sensors and then outputting corresponding first and second magnetic induction signals (Ix, Iy);

normalizing the first and second magnetic induction signals (Ix, Iy) by multiplying either the first magnetic induction signals (Ix) by the ratio R2 or the second magnetic induction signals (Iy) by the ratio R1; and

comparing the amplitudes of the first magnetic induction signals (Ix) with the adjusted amplitude of the reference first sine wave signal (RSx) after resetting to zero azimuth, and then comparing the amplitudes of the second magnetic induction signals (Iy) with the adjusted amplitude of the reference

1 second sine wave signal (RSy) after resetting to zero azimuth, the actual azimuth
2 angle can be obtained accordingly.

3 An actual example is to be explained below by applying the above-
4 mentioned method of measuring the azimuth and resetting to zero azimuth
5 automatically.

6 Since the positive and negative sides of the first and second sine wave
7 signals (RSx , RSy) having reset to zero azimuth are of equal amplitude, it is
8 possible to represent the azimuth with a full circle, which is sub-divided into four
9 different quadrants. The principles behind the method of measuring the azimuth
10 and resetting to zero azimuth automatically are to be explained in conjunction
11 with Fig. 4.

12 adjusting the amplitudes of the first and second magnetic induction
13 signals (I_x , I_y) is to make the magnetic induction signals (I_x , I_y) fall into one of
14 the quadrants in the full circle; subtracting the first and second magnetic
15 induction signals (I_x , I_y) by the average values (X_{base} , Y_{base}) is to determine in
16 which quadrant the first and second magnetic induction signals (I_x , I_y) are
17 located; if the difference values ($I_x - X_{base}$, $I_y - Y_{base}$) are both positive, it can be
18 determined that the two magnetic induction signals (I_x , I_y) are located in the first
19 quadrant.

20 The next step is to compute the azimuth. Since the magnetic induction
21 signals (I_x , I_y) are represented by the full circle, it is necessary to determine
22 whether the amplitudes of the two magnetic induction signals (I_x , I_y) are equal; if
23 yes, the azimuth should lie in the 45 degree quadrant; otherwise, the two
24 magnetic induction signals (I_x , I_y) are plugged into a trigonometric function to

1 find the value for computing the phase angle (θ).

2 According to the present invention, the sampling and normalization
3 process for resetting to zero azimuth can be conducted using samples taken from
4 different positions within the longitudinal and latitudinal coordinates, without
5 affecting the accuracy of the azimuth. To facilitate the finding of the azimuth, the
6 computation task can be largely managed by a microprocessor. To further
7 enhance the practical value, an azimuth meter can be incorporated into a laser-
8 operated distance measuring apparatus to render fully integrated functions.

9 The foregoing description of the preferred embodiments of the present
10 invention is intended to be illustrative only and, under no circumstances, should
11 the scope of the present invention be so restricted.